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EPA METHOD STUDY 33

IGNITABILITY CHARACTERISTICS OF SOLIDS

by

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16. ABSTRACT

The objective of this research was to conduct an interlaboratory study to estimate the precision of three ignitability test methods for solid wastes: radiant heat ignition, flame propagation and water extinguishability. The study consisted of two phases. The first phase involved the replicate measurements of two well characterized test materials and a reference material by nine laboratories. The second phase included similar replicate measurements of seven varied test materials by up to five laboratories.

The study results indicated that not all sample types are amenable to measurement by each test. Although all of the procedures showed some deficiency, the test results indicated that, with some changes in test chamber design they are potentially useful as routine methods.

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FOREWORD

Environmental measurements are required to determine the quality of ambient waters and the character of wastes and waste effluents. The Environmental Monitoring and Support Laboratory - Cincinnati (EMSL-Cincinnati) conducts research to:

- Develop and evaluate techniques to measure the presence and concentration of physical, chemical, and radiological pollutants in water, wastewater, bottom sediments, and solid wastes.
- Investigate methods for the concentration, recovery, and identification of viruses, bacteria, and other microorganisms in water.
- Provide for an Agency-wide quality assurance program to assure standardization and quality control of systems for monitoring water and wastewater.

This publication of the EMSL-Cincinnati, entitled: "USEPA Method Study 33. Ignitability Characteristics of Solids" reports the results of a study of three separate ignitability parameters; radiant heat ignition, flame propagation, and water extinguishability. Federal agencies, states, municipalities, universities, private laboratories, and industry should find this evaluative study helpful in their efforts to establish ignitability criteria for solid and hazardous wastes.

Robert L. Booth
Director, EMSL-Cincinnati

ABSTRACT

The objective of this research was to conduct an interlaboratory study to estimate the precision of three ignitability test methods for solid wastes: radiant heat ignition, flame propagation and water extinguishability. The study consisted of two phases. The first phase involved the replicate measurements of two well characterized test materials and a reference material by nine laboratories. The second phase included similar replicate measurements of seven varied test materials by up to five laboratories.

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SECTION 1

INTRODUCTION

The United States Environmental Protection Agency (USEPA) has specified in the Federal Register (1) that a solid waste exhibits the characteristic of ignitability if "it is capable of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard." At the present time, there are no suitable, validated procedures for determining the ignitability characteristics of solid (non-liquid) wastes.

The objective of this interlaboratory study was to assess precision and potential of application of three ignitability tests; radiant heat ignition, flame propagation, and water extinguishability. This report contains a description of this study, an assessment of the three tests of ignitability characteristics and recommendations for further development of the methods.

SECTION 2

SUMMARY

This evaluation, the first for evaluation of potential testing methods for solids, was performed at the Research Triangle Institute (RTI) (2). Techniques for ignitability measurements were developed and tested on a variety of waste materials. Three ignitability characteristics, radiant heat ignition time, flame propagation rate and water extinguishability were tested on seven waste materials by three to five laboratories. Measured values for each test were statistically analyzed. The overall means, precisions and percent relative standard deviations for all waste types are shown in Table 1.

Based on the data acquired, the following conclusions were made.

- Major problems with equipment and procedural details were discovered in this collaborative effort. These deficiencies must be corrected before the methods can be collaboratively tested or recommended for use as standard procedures.

- Two of the largest sources of error arise from the recording methods used and lack of precise beginning and end points of the tests.

- The three methods tested are potentially useful for evaluating the ignitability hazards posed by solid wastes, nowever, considerable standardization and automation of the test procedures will be required.

- Exposure of some waste types (cotton fiber, polyurethane foam) to a radiant heat source is not sufficient to ignite the samples.

- The flame propagation and water extinguishability tests could not be performed on petroleum-based wastes, as the wastes were not readily ignitable by a flame as specified in the method.

TABLE 1. Phase II Statistical Summary

Test Material	Radiant Heat Ignition $\bar{\bar{X}}$ (Sec)	S_r	S	%RSD	Flame Propagation $\bar{\bar{X}}$ (cm/sec)	S_r	S	%RSD	Water Extinguishability $\bar{\bar{X}}$ (mL)	S_r	S	%RSD
No. 3 Cotton Fiber												
Day 1	ND				4.3 (n=3)	1.4	2.3	53.8	4.3(n=4)	0.5	3.0	69.4
Day 2	ND				2.6 (n=1)	*	*	*	2.4(n=3)	1.5	1.3	55.3
No. 4 Polyurethane Foam												
Day 1	ND				0.3 (n=3)	0.05	0.07	21.4	33.3(n=3)	2.3	2.6	77.6
Day 2	ND				0.3 (n=1)	*	*	*	4.0(n=2)	0.5	2.4	61.0
No. 5 Paint Waste												
Day 1	98(n=5)	52	56	58	0.04(n=4)	0.1	0.01	28.8	2.3(n=4)	0.7	1.1	49.2
Day 2	104(n=4)	25	63	60	0.03(n=2)	0.005	0.004	13.6	2.8(n=3)	0.8	1.3	44.8
No. 6 Waste Oil												
Day 1	119(n=4)	17	38	32	ND				4.9(n=1)	*	*	*
Day 2	151(n=4)	23	152	101	ND				2.8(n=1)	*	*	*
No. 7 Waste Oil/Sand												
Day 1	151(n=4)	39	68	45	ND				2.5(n=1)	*	*	*
Day 2	127(n=4)	6	63	50	ND				2.9(n=1)	*	*	*
No. 8 Waste Solvent												
Day 1	61(n=5)	14	23	38	0.1 (n=3)	0.1	0.1	100.0	4.9(n=3)	0.8	2.5	50.8
Day 2	49(n=4)	6	9	19	0.1 (n=1)	*	*	*	5.2(n=2)	0.6	2.2	41.9
No. 9 Sawdust/Kerosene												
Day 1	16(n=5)	6	6	35	0.11(n=4)	0.04	0.11	104.3	2.7(n=4)	1.1	1.4	51.8
Day 2	14(n=4)	3	3	24	0.20(n=2)	0.03	0.02	12.3	2.9(n=3)	0.8	1.3	43.2

* = value cannot be calculated from existing data
n = number of laboratories reporting data
ND = No data reported

SECTION 3

RECOMMENDATIONS

Based on the study results, observations regarding the methodology, and comments from study participants, the following recommendations are presented for future work:

- For the radiant heat ignition test, develop an automated system which activates the radiant heat source when the chamber interior reaches the desired temperature.
- Introduce an elapsed time device to accurately measure beginning and end points of the radiant heat and flame propagation tests.
- To avoid false starts, lengthen the sample trough used in the flame propagation test so that sample may be ignited without activating the first thermocouple. A narrower trough would also minimize misdirected propagation, giving more consistent results.
- Develop a mechanism for generating a uniform spray pattern for the water extinguishability test. Automate the spray pulsing system to maximum extent possible. Incorporate a more accurate means of measuring water delivery volume.
- Define the exact endpoint of the extinguishability test.

SECTION 4

DESCRIPTION OF STUDY

Test Design

The interlaboratory study was conducted to measure the precision of three measurements of ignitability characteristics of solids. The study was composed of two phases: an initial familiarization phase and a second phase in which an increased number of wastes was evaluated. For each waste type and ignitability characteristic, participants were required to perform six replicate measurements--three on each of two days. Analysis of the reference material was required before and after each triplicate run.

Methodology

The test methods evaluated in this study, ignitability, flame propagation and water extinguishability, were developed as a means of judging the combustion characteristics of waste materials. The details of these methods are presented in Appendix A. The test chamber described in Appendix B was used for all evaluations. In the radiant heat ignition test a radiant heat source is placed 6 cm from the surface of a waste material. Ignition is detected by a thermocouple sensor placed above the sample surface and the time required for ignition is recorded on a strip chart recorder. The rate of flame propagation is measured by recording the time required for a flame to burn a premeasured distance between two thermocouple sensors placed a fixed distance above the sample surface. Results are then expressed as cm/sec. The extinguishability characteristic is measured by igniting the material and, when the surface of the sample is completely aflame, extinguishing with a calibrated spray of water, the volume of which is used as the measure of extinguishability.

Participating Laboratories

Approximately 20 laboratories were contacted by Research Triangle Institute (RTI) for an indication of interest. The initial list of contacts was provided jointly by the Office of Solid Waste (OSW), the Environmental Monitoring and Support Laboratory, Cincinnati (EMSL-Cincinnati), and the American Society for Testing and Materials (ASTM). Representatives of each laboratory were informed of the nature and objective of the study and notified that participation would be on an unpaid basis. Eight laboratories agreed to participate, however, three laboratories of the eight that participated in Phase I withdrew from Phase II of the study. The five remaining laboratories submitted data from the radiant heat ignition test. Four of the five also returned results from the flame propagation and water extinguishability tests. The final study, therefore, included the five laboratories which are listed below:

Dow Chemical Company
Texas Division
Freeport, TX 77541

Guilford Laboratories
827 Huffman Street
Greensboro, NC 27405

Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709

Safety Consultants Engineering, Inc.
5240 Pearl Street
Rosemont, IL 60018

Twin City Testing and Engineering Laboratory, Inc.
662 Cromwell Avenue
St. Paul, MN 55114

Phase I

In this study, an initial Phase I was included to increase the reliability of Phase II measurements by 1) familiarizing the analysts with the ignitability methodologies and 2) insuring accurate calibration and consistent operation of the ignitability apparatus prior to initiation of Phase II. Each of nine laboratories was provided an RTI-built testing apparatus (Appendix B) a reference material, and aliquots of two wastes, chosen because both had been characterized previously in a single-laboratory evaluation (2). Wood wool excelsior was chosen as the reference material because of its use by Underwriters' Laboratories as a standard for class A fire extinguishers and its consistent behavior in the single-laboratory evaluation. A summary of the Phase I data is presented in Section 5, Discussion and Conclusions.

Selection and Preparation of Wastes

The two materials used in Phase I were lignite coal/xylene and red oak sawdust/kerosene mixtures. The lignite coal was dried in a fume hood, ground, and sieved to 40-60 mesh and placed in containers. The material was then spiked with reagent grade xylene and mixed on a rotary blender for 20 minutes to give a 25% (w/w) xylene concentration in the mixture. Red oak sawdust from a sawmill was collected, air dried, placed in containers, spiked with reagent grade kerosene, and mixed on a rotary blender for 20 minutes, yielding a 20% kerosene concentration in the mixture.

Test materials 3 through 9 were used in Phase II of the study. All wastes are described in Table 2.

Table 2. Physical Description of Test Materials

Phase I Materials

1. Coal/Xylene. Lignite coal was ground to approximately 10 mesh and combined with reagent grade xylenes to yield a 25% (w/w) mixture of xylenes and coal.

2. Sawdust/Kerosene. Red oak sawdust was dried for 24 hours at ambient temperature. A mixture of 20% (w/w) reagent grade kerosene and dried red oak sawdust was prepared.

Phase II Materials

3. Cotton Fiber. Commercially available.

4. Polyurethane Foam. A one-inch thick foam of the type used for padding on furniture or in pillows. Submitted as a single piece. Commercially available.

5. Paint Waste. A yellow-colored composite paint waste obtained from a hazardous waste disposal facility. This material had the consistency of putty and a strong acetate odor. There was no apparent separated solvent on surface. Characteristic of paint manufacturing residual.

6. Waste Oil. A composite of used oil collections from local service stations. This material had the consistency of molasses.

7. Waste Oil/Sand. A mixture of a light waste oil, the same as used in Waste No. 6, (60%) and builder's sand (40%). Some stirring needed to maintain sample homogeneity.

8. Waste Solvent. A viscous orange-colored composite of waste materials obtained at Triangle Resources Industries, Reidsville, NC 27320.

9. Same as No. 2.

Section 5

TREATMENT OF DATA

The purpose of the data generated in this collaborative study was to estimate the single and overall precision of measurements of the ignitability characteristics of solid wastes. Because there are no true values associated with the measurements for each material tested, statistical analyses are necessarily limited to estimates of precision. Prior to statistical analyses, all data were tested for outliers using an iterative Cochran's test for homogeneity of variances at the 95% confidence level. According to Cochran, if a standard deviation of one set of replicates is significantly different from the other standard deviations in the group, then that set belongs to a separate population and can be rejected subject to the significance level criteria below. The criteria for the rejection was 0.05 significance level for Cochran's "C" given by the formula shown below:

$$C = \frac{\text{largest } s_i^2}{\Sigma\, s_i^2}$$

s_i = standard deviation of the ith pair of duplicates

Data rejected using Cochran's test are denoted by "**" following the results in Phase II data tables (Appendix C). No further attempts were made to identify outlying data. With the unusually small amount of data returned by study participants it was feared that elimination of erratic but valid data points would occur, biasing the final results.

For each laboratory and waste material, the traditional mean and standard deviation of daily triplicate measurements were calculated. Single-laboratory precision estimates (S_r) were calculated from these data as follows:

Single-Laboratory/Analyst Standard Deviation:

$$S_r = \sqrt{\frac{n_{L1}\, S_{L1}^2 + n_{L2}\, S_{L2}^2 + \ldots + n_{Li}\, S_i^2}{n_{L1} + n_{L2} + \ldots + n_{Li}}}$$

where: n_{Li} = number of replicate determinations performed by laboratory i

S_{Li}^2 = variance of replicate measurements by laboratory i

To characterize the multilaboratory performance of the methods, the overall mean $\bar{\bar{X}}$, the overall precision (S) and the percent relative standard deviation %RSD, were computed as follows:

Overall Mean: $$\bar{\bar{X}} = \frac{1}{n} \sum_{i=1}^{n} \bar{X}_i$$

where: n = number of laboratories
$\bar{X}$ = mean of measurements reported by laboratory i

Overall Precision:

$$S = \sqrt{S_{\bar{x}}^2 + \frac{2\,(S_r)^2}{3}}$$

where $S_{\bar{x}}$ = standard deviation of means of n laboratories

For this study, $S_{\bar{x}}^2$ has been estimated from means of 3 replicate observations in each laboratory, thus it includes all the variability common between laboratories (S_B^2), but only one third of the variability common within each laboratory ($S_r^2/3$). Since we want S to include all variability for a single analysis in any laboratory, therefore for this study:

$$S^2 = S_B^2 + S_r^2 = S_B^2 + \frac{S_r^2}{3} + \frac{2S_r^2}{3} = S_{\bar{x}}^2 + \frac{2S_r^2}{3}$$

Percent Relative Overall Standard Deviation:

$$\%RSD = \frac{S}{\bar{\bar{X}}} \times 100$$

Section 6

DISCUSSION AND CONCLUSIONS

Phase I Results

The importance of requiring participants to analyze preliminary samples prior to the formal study has been shown in previous method validation studies. Such analyses help provide more realistic data by: 1) familiarizing analysts with analytical methods; 2) allowing resolution of equipment or procedural problems; and 3) screening laboratories that are either unwilling or unable to solve analytical difficulties. For this collaborative effort, no attempt was made to disqualify laboratories, but only to familiarize them with the test chambers and samples. Each laboratory received sufficient amounts of each of two test materials for measurement of the three ignitability characteristics. The results of Phase I measurements are shown in Tables 3-5.

The mean ignition times reported by six laboratories for test material 1 (coal/xylene) was 24.0 seconds on day 1 and 24.5 on day 2. Overall precision S of those measurements was 11.1 and 7.8 seconds, respectively, representing relative standard deviations (%RSD) of 46.3 and 32.0 percent. Ignition time measurements on test material 2 (sawdust/kerosene) were times of 16.0 and 23.5 seconds for day 1 and day 2 measurements, respectively, with relative standard deviations of 27.2 and 47.4 percent. The reference material, wood wool excelsior, measured before and after each set of three samples, performed consistently on both days, giving means of 49.5 and 51.4 seconds and relative standard deviations of 14.1 and 5.7 percent. The results obtained from test materials 1 and 2 do not appear to have been influenced significantly, therefore, by fluctuations in the operating characteristics of the test chambers.

Results of flame propagation tests reported by seven laboratories for test material 1 yielded a mean propagation rate of 0.49 and 0.57 cm/sec for day 1 and day 2 measurements, respectively, with relative standard deviations of 43.3 and 25.4%. Precision for test material 2 was slightly poorer, as indicated by day 1 and day 2 relative standard deviations of 40.9 and 50.0%, respectively. Only four laboratories reported flame propagation data for test material 2. All of the remaining laboratories reported that a flame would not propagate over the entire surface of the samples. Since this problem did not occur in the single laboratory evaluation of these methods (2) or in the analysis of the reference material (Table 4), a probable cause of non-propagation was non-homogeneity of the test material. At least one laboratory reported that the contents of separate containers of the same test material differed in appearance.

In the water extinguishability test, the volume of water needed to extinguish a flame on test material 1 was 17.8 mL for both days 1 and 2, with overall precision (S) of 14.5 mL (%RSD 81.3%) and 17.6 mL (98.8%), respectively. Test material 2 fires required an average of 5.9 mL of water in day 1 measurements and 3.0 mL in day 2 measurements. Percent relative standard deviations were 79.1 and 55.1% on day 1 and day 2, respectively, while those for the reference material were 102.9 and 53.3%.

Table 3. Phase I Results - Radiant Heat Ignition Test

Test Material 1: Coal/Xylene

			Laboratory No.						Summary Statistics			
			101	102	105	106	107	111	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (Sec)	$\bar{X}$	19.0	22.7	23.0	16.5	45.8	17.3	24.0			
	Std. Deviation	S	1.6	1.3	1.0	1.7	3.8	1.7		2.0	11.1	46.3
	Variance	S^2	2.3	1.6	1.0	3.0	14.4	2.9				
Day 2	Sample Mean (Sec)	$\bar{X}$	22.2	28.0	25.3	18.8	36.7	16.2	24.5			
	Std. Deviation	S	1.2	0.6	5.7	1.2	5.8	1.2		3.4	7.8	32.0
	Variance	S^2	1.4	0.4	32.3	1.6	33.9	1.4				

Test Material 2: Sawdust/Kerosene

			Laboratory No.						Summary Statistics			
			101	102	105	106	107	111	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (Sec)	$\bar{X}$	13.2	21.5	87.2*	13.3	37.5*	16.2	16.0			
	Std. Deviation	S	2.9	2.2	68.3*	2.9	22.7*	1.2		2.4	4.3	27.2
	Variance	S^2	8.4	4.8	4664*	8.3	515*	1.4				
Day 2	Sample Mean (Sec)	$\bar{X}$	16.7	24.2	40.0	20.3	ND	16.2	23.5			
	Std. Deviation	S	3.8	3.8	11.0	4.8		6.1		6.5	11.1	47.4
	Variance	S^2	14.8	14.6	121	22.6		37.9				

* = Data rejected as outliers by Cochran's test
ND = No Data reported or sample did not ignite

Table 3: Phase I Results - Radiant Heat Ignition Test

Reference Material

			Laboratory No.						Summary Statistics			
			101 (n=2)	102 (n=4)	105 (n=3)	106 (n=4)	107	111 (n=4)	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (Sec)	$\bar{X}$	54.2	49.3	53.7	43.0	ND	47.1	49.5			
	Std. Deviation	S	2.3	0.9	11.0	7.4		4.5				
	Variance	S^2	5.4	0.8	121.0	55.1		20.2		6.3	7.0	14.1

			Laboratory No.						Summary Statistics			
			101 (n=3)	102 (n=4)	105 (n=3)	106 (n=4)	107	111 (n=4)	$\bar{\bar{X}}$	S_r	S	%RSD
Day 2	Sample Mean (Sec)	$\bar{X}$	51.0	50.6	50.7	94.4*	ND	53.4	51.4			
	Std. Deviation	S	1.7	4.3	3.8	8.4*		1.9		3.2	2.9	5.7
	Variance	S^2	2.8	18.6	14.3	70.6*		36				

* Data rejected by Cochran's test
ND = No data; sample did not ignite

Table 4. Phase I Results - Flame Propagation Test

Test Material 1: Coal/Xylene

		Laboratory No.							Summary Statistics			
		101	102	105	106	107	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (cm/Sec) $\bar{X}$	0.33	0.54	0.57	0.31	0.80	0.49	0.36	0.49			
	Std. Deviation S	0.02	0.18	0.13	0.11	0.26	0.09	0.09		0.15	0.21	43.3
	Variance S^2	0.0005	0.03	0.02	0.01	0.07	0.01	0.01				
Day 2	Sample Mean (cm/Sec) $\bar{X}$	0.39	0.68	0.63	0.65	0.62	0.52	0.48	0.57			
	Std. Deviation S	0.05	0.04	0.15	0.16	0.22	0.03	0.10		0.12	0.14	25.4
	Variance S^2	0.002	0.002	0.02	0.02	0.05	0.001	0.01				

Test Material 2: Sawdust Kerosene

		Laboratory No.							Summary Statistics			
		101	102	105	106	107	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (cm/Sec) $\bar{X}$	ND	0.10	ND	ND	0.06	0.03	0.07	0.06			
	Std. Deviation S		0.01			0.04	0.01	0.03		0.03	0.02	40.9
	Variance S^2		0.0001			0.001	0.002	0.001				
Day 2	Sample Mean (cm/Sec) $\bar{X}$	ND	0.08	ND	ND	0.01	0.14*	0.02	0.04			
	Std. Deviation S		0.01			0.003	0.20*	0.003		0.02	0.02	50.0
	Variance S^2		0.0001			-	0.04*	-				

* = Data rejected by Cochran's test
ND = No data reported. No flame propagation

Table 4. Phase I Results - Flame Propagation Test

Reference Material

			Laboratory No.							Summary Statistics			
			101 (n=2)	102 (n=4)	105 (n=4)	106 (n=2)	107 (n=4)	111 (n=4)	112 (n=4)	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (cm/Sec)	$\bar{X}$	0.48	0.46	0.51	0.32	0.40	0.33	0.38	0.41			
	Std. Deviation	S	0.03	0.03	0.05	0.014	0.01	0.04	0.04		0.03	0.08	19.0
	Variance	S^2	0.001	0.001	0.003	0.002	0.0001	0.001	0.001				

			Laboratory No.							Summary Statistics			
			101 (n=2)	102 (n=4)	105 (n=4)	106 (n=2)	107 (n=4)	111 (n=4)	112 (n=4)	$\bar{\bar{X}}$	S_r	S	%RSD
Day 2	Sample Mean (cm/Sec)	$\bar{X}$	0.43	0.50	0.52	0.41	0.40	0.37	0.35	0.42			
	Std. Deviation	S	0.11	0.07	0.03	0.11	0.04	0.05	0.025		0.06	0.08	19.1
	Variance	S^2	0.01	0.004	0.001	0.01	0.002	0.003	0.001				

Table 5. Phase I Results - Water Extinguishability Test

Test Material 1: Coal/Xylene

		Laboratory No.							Summary Statistics			
		101	102	105	106	107	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (mL) $\bar{X}$	11.3	39.2	35.4	6.3	17.3	7.5	7.6	17.8			
	Std. Deviation S	0.7	7.7	8.7	1.7	5.9	2.6	1.9		5.1	14.5	81.3
	Variance S^2	0.5	58.8	74.9	2.8	35.6	7.0	3.5				
Day 2	Sample Mean (mL) $\bar{X}$	9.6	41.9	38.3	8.7	78.0*	7.1	1.4	17.8			
	Std. Deviation S	7.1	2.1	5.4	3.0	32.3*	2.7	0.3		1.8	17.6	98.8
	Variance S^2	50.4	4.5	29.6	9.1	1045*	7.5	0.1				

Test Material 2: Sawdust/Kerosene

		Laboratory No.							Summary Statistics			
		101	102	105	106	107	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (mL) $\bar{X}$	ND	3.8	5.3	5.3	8.6*	1.8	13.2	5.9			
	Std. Deviation S		0.6	2.7	2.1	8.1*	1.0	2.71		2.1	4.7	79.1
	Variance S^2		0.4	7.1	4.3	66.8*	1.0	7.3				
Day 2	Sample Mean (mL) $\bar{X}$	ND	3.9	5.1	3.6	1.4	2.5	1.4	3.0			
	Std. Deviation S		0.6	0.9	1.7	0.5	1.3	0.2		0.9	1.7	55.1
	Variance S^2		0.3	0.9	2.8	0.3	1.6	0.04				

* = Data rejected as outliers by Cochran's test
ND = No data reported. Sample did not ignite

Table 5. Phase I Results - Water Extinguishability Test

Reference Material

		Laboratory No.							Summary Statistics			
		101 (n=2)	102 (n=4)	105 (n=4)	106 (n=4)	107 (n=4)	111 (n=4)	112 (n=4)	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1	Sample Mean (mL) $\bar{X}$	11.4	4.1	3.5	3.6	8.7	1.2	1.2	4.8			
	Std. Deviation S	7.2	0.5	0.7	0.3	8.1	0.3	0.2		3.8	4.9	102.9
	Variance S^2	52.3	0.3	0.6	0.1	65.3	0.1	0.03				
Day 2	Sample Mean (mL) $\bar{X}$	5.1	3.5	3.7	3.0	3.8*	1.2	1.5	3.0			
	Std. Deviation S	0.3	0.5	1.1	1.3	3.7*	0.6	0.4		0.8	1.6	53.3
	Variance S^2	0.1	0.3	1.3	1.7	13.4*	0.3	0.2				

Outliers

Because of the small amount of data received for Phases I and II, minimal outlier testing was performed. During Phase I, the number of data sets ranged from 4 to 7. For these data, only Cochran's test was applied to eliminate laboratories with the worst precision. Those laboratories had in most cases, also returned study data that were abnormally high as compared to other laboratories. In Phase I, 5 of 71 triplicate measurements were rejected while in Phase II, 1 of 98 triplicates were rejected.

Phase II Results

A compilation of the raw data obtained during Phase II of the study can be found in Tables 6-22 (Appendix C). Only five Phase II laboratories reported radiant heat ignition data. Four of those five also reported flame propagation and water extinguishability results. Ideally, each of the responding laboratories should have returned complete data sets for seven waste types for each of the three ignitability tests. Test materials 3 and 4, cotton fiber and polyurethane foam, respectively, failed to ignite within five minutes under the radiant heat source. The radiant heat ignition procedure was performed, therefore, on only five sample types by five laboratories.

The flame propagation test yielded even fewer useable data than the radiant heat test. Test materials 6 and 7 could not be analyzed by the procedure. For this test, five test materials were examined by an average of only three laboratories, making statistical evaluation of the methods difficult. Likewise, in the water extinguishability test, three to four laboratories reported data from five test materials.

Statistical Summary and Precision Statement

For ease of discussion of the radiant heat ignition, flame propagation, and water extinguishability tests of Phase II, the statistical portions of Tables 6-22 (Appendix C) have been combined in Table 1. Five test materials were analyzed by each of the three tests. Since only one laboratory reported extinguishability data for test materials 6 and 7, those data are not being considered in this discussion. Radiant heat ignition measurements yielded overall percent relative standard deviations in the range of 19-101%. Data obtained from flame propagation and extinguishability tests, had relative standard deviations of 12.3-100.0% and 41.9-77.6%, respectively.

Evaluation of Methods

The quantity of data from Phase II laboratories was considerably smaller than required for a meaningful statistical evaluation of the ignitability methods. Thorough correlation of results of the three methods for each test material is not possible because in most cases only two tests were performed on each waste. Examination of the data in Table 1, however, reveals considerable variation in both single-laboratory and overall precisions for all three tests. It is not possible to state which test exhibits the greatest

variability either day-to-day or across waste types. The most reliable evaluation of the methods is likely therefore, to be qualitative. As part of the study, participants were encouraged to submit narratives of their experiences with the test apparatus, and to provide comments as to the applicability of the methods to waste characterization. One laboratory observed while conducting the radiant heat ignition test that the relationship between the rheostat setting and the source temperature was not constant. As a result, replicate radiant heat measurements were highly variable even at the same rheostat setting. Another laboratory noted that the interior temperature of the chamber changed as a function of the length of time the instrument was in use and soot deposited on the chamber walls and heat source. It was further noted that fluctuations in interior chamber temperature resulted when the chamber door was opened to introduce samples. Since ignition times are dependent on chamber temperature at the beginning of the test, a second heat source should be introduced to the chamber accompanied by automatic activation of 1) the radiant heat source at a predetermined chamber temperature and 2) a timing device that would measure and record time elapsed between activation of the heat source and a signal from the flame-detecting thermocouple. This would eliminate the need for a strip chart recorder, which in this study was itself the source of considerable error. The test procedure requires a chart speed of 0.5 inches/minute (0.02 cm/sec). Since the chart distances recorded in the study were commonly in the 0.2-0.4 cm range, a possible 10-20% error was introduced by the recording step alone.

Operational difficulties were also experienced in the flame propagation test. The leading cause for the small amount of data was non-propagation of the flame or non-ignition. One laboratory reported that the propagation rate for some samples depended on the depth of the sample in the trough. One analyst reported that flames had a tendency to propagate erratically or in the opposite direction of the second thermocouple. A narrower trough would minimize the possibility of misdirected propagation. Some false starts were reported when ignition of the sample was attempted. This problem could be solved by lengthening the trough so that the sample can be ignited without activating the first thermocouple.

In the water extinguishability test, several factors undoubtedly contributed to the overall error of the measurements. Perhaps the greatest source of error was the confusion over whether extinguishment of only visible flames or also the embers constituted the endpoint of the analysis. If the latter endpoint is assumed, larger amounts of water would be used. Modifications in the water delivery system would solve some problems which were reported by analysts. The system is designed to deliver a cone-shaped spray, the diameter of which is the same as that of the sample dish. More accurate results might be achieved by using a spray pattern that delivers water to the entire surface of the sample. Direct measurement by weight, of the amount of water delivered to the flaming sample would be preferable to calculating the value from time and delivery rate, both of which contribute separately to the total error of the extinguishability measurement.

The three ignitability tests studied in this collaborative effort have the potential of being useful and precise techniques for determining the potential ignition hazard of solid wastes. Before the methods, particularly the water extinguishability test, can be considered fully reliable, substantial modifications and refinements of the test chamber itself are mandatory. Many of those modifications have been discussed in this section, but only further testing on actual waste samples will determine the extent of the changes ultimately required.

In the current study, although eight laboratories agreed to participate in the full study, data/test were reduced to as few as three sets, resulting in only limited statistical treatment of the results and evaluation of the methods. Once the method is refined, the ignitability tests should again be collaboratively tested with sufficient laboratories that are paid, if necessary, to assure full participation.

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APPENDIX A
IGNITABILITY METHODS
RADIANT HEAT IGNITION TEST PROCEDURE

1.0 SUMMARY OF THE METHOD

A sample is placed 6 cm beneath a preheated radiant heat source and the time to ignition detected by a thermocouple sensor and recorded on a strip chart recorder.

2.0 APPARATUS AND REAGENTS

2.1 Test chamber - as shown in Figure 1.
2.2 Sample container - aluminum weighing pan, 6 cm diameter X 1.7 cm deep.
2.3 Controller/sensor - as shown in Figure 1.
2.4 Recorder - strip chart, variable speed and input impedance.
2.5 Safety Equipment
  2.5.1 Flameproof gloves (Lab Safety Supply 1915M or equivalent)
  2.5.2 Tongs - 53 cm (Fisher, 15-207 or equivalent)
  2.5.3 Respirator (Fisher, 13-995-11 or equivalent)
2.6 Balance (minimum accuracy to nearest 100 mg)

3.0 TEST PROCEDURE

3.1 Locate the test chamber in a fireproof fume hood with the exhaust fan turned on.
3.2 If the hood is large enough, locate the controller/sensor and the recorder outside the hood but in proximity to the test chamber.
3.3 With an empty sample container on the sample platform, (Figure 1; part no. 5) position the sample platform to provide a heating element (Figure 1; part no. 1) to sample container (top rim) distance of 6 cm.
3.4 Position the thermocouple (Figure 1; part no. 7) 1 cm above the top rim and centered over the sample container.
3.5 Connect the thermocouple to position 33 (Figure 1) on the controller/sensor using the cable supplied.
3.6 Connect the heater/solenoid cable (Figure 1; part no. 16, 17) to position 34 (Figure 1) on the controller/sensor.
3.7 Connect the power cord on the controller/sensor to a 110 VAC power source.
3.8 Set the variable transformer to 0.
3.9 Position a dummy (blackened with carbon soot) sample container (centered) under the heat source. Close the chamber door.
3.10 Turn on the controller/sensor.
3.11 Turn on the heater. Set the variable transformer to the setting determined during the temperature adjustment procedure.
3.12 Preheat the radiant heat source for 30 minutes.
3.13 Transfer sample to the sample container to a depth of approximately 1 cm, making sure that the sample surface is level and smoothed.

WARNING

Extreme care must be exercised in testing materials known or suspected of being extremely flammable. Preliminary tests using greatly diminished sample sizes should be conducted prior to performing the actual test to insure the safety of the analyst. A reduced test sample depth should be used in cases where sample ignition is extremely rapid and/or violent.

3.14 Place the filled sample container outside, but in proximity to, the test chamber.

3.15 Start the recorder at a chart speed of 0.5 in/min and a full-scale sensitivity of 1 volt/inch.

3.16 Open the chamber door and remove the dummy sample container.

3.17 Using tongs and flameproof gloves, pick up the filled sample container and place it, centered, under the radiant heat source. Immediately mark the recorder chart by gently touching the tip of the thermocouple with the tongs. Lower the door on the test chamber.

CAUTION

The placement of the sample beneath the radiant heat source, the marking of the recorder chart and the closing of the chamber door must be executed as quickly as possible to optimize the precision of the test results.

3.18 Raise the chamber door and remove the ignited sample from beneath the radiant heat source and carefully place it in the bottom of the chamber.

WARNING

Raise the fume hood and test chamber doors just to a level that facilitates removal of the sample from beneath the radiant heat source. Flameproof gloves should be used in combination with tongs to protect the analyst from the burning sample.

3.19 Extinguish the fire by smothering.

3.20 Prepare the chamber for the next sample by positioning the dummy sample container beneath the radiant heat source.

3.21 Lower the fume hood door to one-half the height of the chamber.

3.22 Measure the distance (cm) from the initial mark to ignition on the recorder. Calculate the time to ignition from the calibrated recorder speed.

3.23 Proceed with the analysis of subsequent samples by repeating steps 3.13 through 3.22.

FLAME PROPAGATION TEST PROCEDURE

1.0 SUMMARY OF THE METHOD

A sample is placed in an aluminum trough and ignited at one end. The time required to burn a premeasured distance is sensed by thermocouples and recorded on a two-pen strip chart recorder.

2.0 APPARATUS AND REAGENTS

2.1 Test chamber - as shown in Figure 1.
2.2 Sample container - prepared by molding heavy-duty aluminum foil in a 20.5 X 6.6 X 3.5 cm (inside dimensions) stainless steel trough.
2.3 Controller/sensor - as shown in Figure 1.
2.4 Recorder - two-pen, strip chart, variable speed and input impedance.
2.5 Safety Equipment
  2.5.1 Flame proof gloves (Lab Safety Supply, 1915M or equivalent)
  2.5.2 Tongs - 53 cm (Fisher, 15-207 or equivalent)
  2.5.3 Respirator (Fisher, 13-995-11 or equivalent)
2.6 Wood splints

3.0 TEST PROCEDURE

3.1 Locate the test chamber in a fireproof fume hood with the exhaust fan turned on.
3.2 If the hood is large enough, locate the controller/sensor and the recorder in the hood. If sufficient space is not available in the hood, locate the controller/sensor and/or the recorder outside the hood but in proximity to the test chamber.
3.3 Connect the thermocouples, located in the bottom of the test chamber, to the strip chart recorder.
3.4 Prepare the sample container by molding heavy-duty aluminum foil in the stainless steel trough.
3.5 Transfer sample to the sample container to a depth of approximately 1 cm, making sure that the sample surface is even and smoothed.

WARNING

Extreme care must be exercised in testing materials known or suspected of being extremely flammable. Preliminary tests using greatly diminished sample sizes should be conducted prior to performing the actual test to insure the safety of the analyst. A reduced sample depth should be used in cases where sample ignition is extremely rapid and/or violent.

3.6 Place the filled sample container centered between the two thermocouples in the bottom of the test chamber.
3.7 Start the recorder at a chart speed of 0.5 in/min and a full-scale sensitivity of 100 millivolts/inch.
3.8 With a lighted wood splint, ignite the sample at one end of the trough. Immediately lower the test chamber door.
3.9 Lower the fume hood door to one-half the height of the test chamber.

3.10 Record the distance (cm) between the two thermocouples and the linear distance traveled by the recorder (cm) pen during the burn period.

NOTE

If the flame does not propagate the full distance between the thermocouples, manually measure the distance propagated and the distance travelled by the recorder pen.

3.11 Raise the fume hood and test chamber doors slightly. Cover the sample with the stainless steel trough lid.

WARNING

The fume hood and test chamber doors should be raised only as high as required to cover the burning sample. Flameproof gloves should be used in combination with tongs to protect the analyst from the burning sample.

3.12 Prepare the chamber for the next sample by removing the extinguished sample.

WATER EXTINGUISHABILITY TEST PROCEDURE

1.0 SUMMARY OF THE METHOD

An ignited sample is placed 6 cm beneath a sprayer nozzle and extinguished by delivering water at a calibrated rate to the sample. The volume of water required to extinguish the sample is determined from the duration of the spray and the flow rate of water.

2.0 APPARATUS AND REAGENTS

2.1 Test chamber - as shown in Figure 1.
2.2 Sample container - aluminum "tart" pan, 1.5 cm diameter (top, inside) X 3.2 cm deep.
2.3 Controller/sensor - as shown in Figure 1.
2.4 Recorder - strip chart, variable speed and input impedance.
2.5 Safety Equipment
  2.5.1 Flameproof gloves (Lab Safety Supply, 1915M or equivalent)
  2.5.2 Tongs - 53 cm (Fiaher, 13-995-11 or equivalent)
  2.5.3 Respirator (Fisher, 13-995-11 or equivalent)
2.6 Balance (minimum accuracy to nearest 100 mg)
2.7 Wood splints
2.8 Water - municipal supply

3.0 TEST PROCEDURE

3.1 Locate the test chamber in a fireproof fume hood with the exhaust fan turned on.
3.2 If the hood is large enough, locate the controller/sensor and the recorder in the hood. If sufficient space is not available in the hood, locate the controller/sensor and/or the recorder outside the hood but in proximity to the test chamber.
3.3 Connect the copper tubing containing the water pressure regulator and gauge to a suitable supply source using the brass fitting (3/8" male NPT - 1.4" tube) provided.

CAUTION

This tubing should be connected to a water supply source with the regulator and gauge located close to the source. If the fitting supplied for this connection is incorrect, substitute the appropriate alternative.

3.4 Connect the long end of the copper tubing to the solenoid valve (Figure 1, part no. 13).
3.5 Install the sprayer nozzle (Figure 1, part no. 10) in the bulkhead fitting on the inside right side of the test chamber.
3.6 Turn on the water at the source and test for leaks. Tighten fittings as required.
3.7 Set the water pressure to the solenoid valve to 10 psi.
3.8 Position the sample platform centered and exactly 6 cm under the sprayer nozzle.

3.9 Place the aluminum divider between the support brackets located near the bottom of the test chamber.
3.10 Turn on the power to the controller/sensor.
3.11 With an empty sample container on the sample platform, activate the sprayer continuously for 1 minute to eliminate air from the copper tubing.
3.12 Read the water pressure (in the absence of flow) from the pressure gauge. Adjust to 10 psi, if necessary.
3.13 Activate the sprayer in several short bursts and again note the water pressure. Adjust, if necessary.
3.14 Repeat step 3.12 until the pressure gauge reads 10 psi without flow/
3.15 Using an empty sample container, activate the sprayer in twenty short bursts (approx. 100 millisecond), approximately 1 second apart. Record the cumulative time.
3.16 Carefully transfer the water in the sample container to a 25 mL grduated cylinder. Record the volume delivered.
3.17 Calculate the water flow rate in milliliters per second.
3.18 Transfer sample to the sample container to a depth of 1 cm, making sure that the sample surface is level and even.

WARNING

Extreme care must be exercised in testing materials known or suspected of being extremely flammable. Preliminary tests using greatly diminished sample sizes should be conducted prior to performing the actual test to insure the safety of the analyst. A reduced test sample depth should be used in cases where sample ignition is extremely rapid and/or violent.

3.19 Place the sample on the aluminum divider near the bottom of the test chamber.
3.20 Ignite the sample, in the center, with a lighted wood splint. Lower the test chamber door completely and the fume hood door to one-half the height of the chamber.
3.21 Allow the fire to burn until the entire surface of the sample is burning.
3.22 Open the fume hood and chamber doors. Using tongs, center the ignited sample on the sample platform directly beneath the sprayer nozzle.
3.23 Lower the test chamber door completely and the fume hood door to one-half the height of the test chamber.
3.24 Depress the switch which activates the sprayer and timer, in short bursts (approximately 100 milliseconds), approximately 1 second apart and observe for continued burning between bursts.

CAUTION

This delivery process mayn require practice before it can be executed successfully.

3.25 Record the time to extinguishment to the nearest 0.01 seconds.
3.26 If the water was not effective in extinguishing the fire, extinguish the flame by smothering.
3.27 Prepare the test chamber for the next sample by resetting the timer and removing the extinguished sample.

APPENDIX B

IGNITABILITY TEST CHAMBER

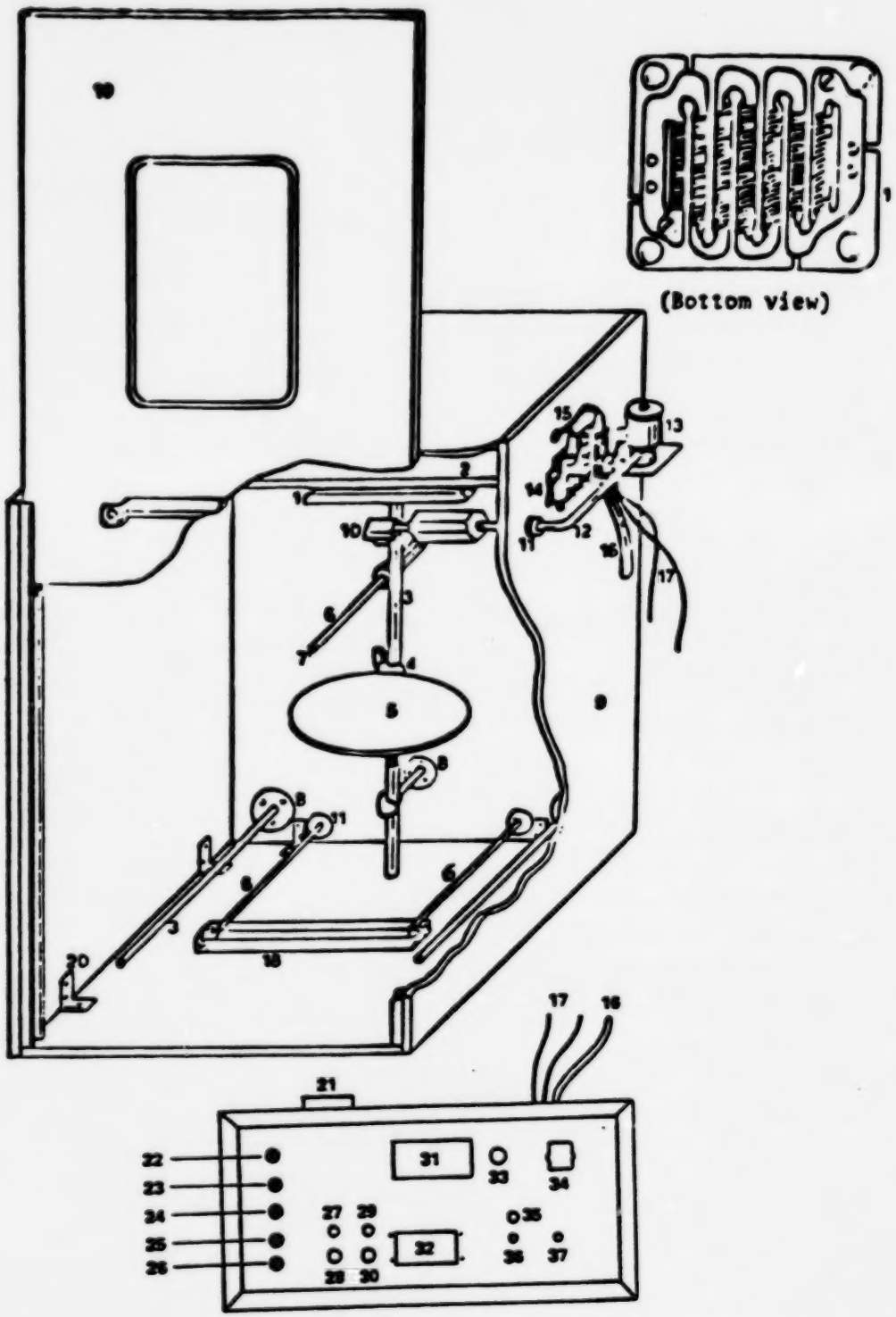

Figure 1. **Ignitability Test Chamber and Controller/Sensor.**

PARTS LIST

Part No.	Description
1	Heater, 750 watt, 120 volt (American Scientific Products, 61856); lower clay assembly for Precision Kjeldahl flask heater; element cemented to ceramic base with Savereisen sealing cement (No. 33 powder).
2	Heater support, Unistrut P-1000.
3	Aluminum rod, 1/2 in diameter (Fisher, 14-666).
4	Right angle connector (Fisher, 14-666-20).
5	Plate support (Fisher, 14-666-24).
6	Thermocouple protection tube, Omegatite 450®, 3.16 × 1/4 × 12 in (Omega Engineering, PTRA31614-12); with closed end sawed off.
7	Thermocouple, sub-miniature, Type K, Inconel sheath, 0.020 × 12 in (Omega Engineering, SCAIN-020U-12); Thermocouple extension (Omega Engineering, EXTT-K-24); Thermocouple connectors.
8	Foot plate (Fisher, 14-666-25)(Omega Engineering, SMP-K-MP).
9	Transite® box, 45 × 45 × 60 cm, hinged top.
10	Hollow spray nozzle, stainless steel, 1/4 × 1-5/16 in male (McMaster-Carr Supply® 34505K76); female connector, 1/4 × 1/4 in NPT (Swagelok®, SS-400-7-4).
11	Bulkhead union, stainless steel, 1/4" (Swagelok®, SS-400-61).
12	Tubing, stainless steel, 1/4 in O.D.
13	Solenoid valve, 1/4 in, normally closed (McMaster-Carr Supply, 4639R58).
	Not shown: Copper tubing, 1/4 in O.D.; pressure gauge, 0-15 psi (Matheson, 63-3115); water pressure regulator (Fisher, 15-529); Female branch tee, 1/4 × 1/4 in NPT (Swagelok®, SS-400-3-4TTF).
14	Terminal board, double row (Kulka, 601-GP-2).
15	High temperature cable, copper, 14AWG (W.K. Hile, 9G-P14T-1); solderless connector, spade terminals.
16	Cable, 2 conductor, 18AWG copper (power supply to heater).
17	Cable, single conductor, 18AWG.
18	Chromatography trough (Fisher, 15-729,54).
19	Door, Transite®, sliding; thermal-resistant glass window.
20	Angle bracker, 4 hole.

PARTS LIST (cont'd.)

21	Auto transformer.
22	Fuse holder, power.
23	Fuse holder, meters.
24	Fuse holder, heater controller.
25	Fuse holder, heater.
26	Fuse holder, spray.
27	Neon lamp, power.
28	SPST toggle switch, power.
29	Neon lamp, heater control.
30	SPST toggle switch, heater control.
31	Omega Model 650, digital thermocouple thermometer.
32	IMC Model 402, digital timer.
33	Miniature thermocouple jack.
34	Nine-pin Molax connector/panel mount.
35	Neon lamp, sprayer.
36	Double pole, double throw, center off, momentary/on-on miniature toggle switch (for sprayer).
37	Minature push button switch, momentary switch (timer reset).

APPENDIX C
PHASE II DATA

Table 6. Phase II Results - Radiant Heat Ignition Test

Test Material No. 5 - Paint Waste

		Laboratory No.					Summary Statistics			
		101	102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1										
Mean (Sec)	$\bar{X}$	69	65	113	155	88	98			
Std. Deviation	S	16	4	15	114	16		52	56	58
Variance	S^2	262	16	231	12990	242				
Day 2										
Mean (Sec)	$\bar{X}$	49	69	183	116	ND	104			
Std. Deviation	S	13	3	45	18			25	63	60
Variance	S^2	176	10	2033	317					

Reference Material

		Laboratory No.					Summary Statistics			
		101	102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1										
Mean (Sec)	$\bar{X}$	50	52	40	51	44	47			
Std. Deviation	S	4	1	0	5	55		25	21	45
Variance	S^2	17	2	0	28	3014				
Day 2										
Mean (Sec)	$\bar{X}$	41	52	42	53	ND	47			
Std. Deviation	S	0	3	3	6			3	7	15
Variance	S^2	0	8	12	36					

ND = No data reported

Table 7. Phase II Results - Radiant Heat Ignition Test

Test Material No. 6 - Waste Oil

		Laboratory No.				Summary Statistics			
		101	102	106	111	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (Sec)	$\bar{X}$	91	124	85	175	119			
Std. Deviation	S	9	7	18	27		17	38	32
Variance	S^2	60	56	325	720				
Day 2									
Mean (Sec)	$\bar{X}$	80	191	85	249	151			
Std. Deviation	S	9	27	23	27		23	152	101
Variance	S^2	81	745	525	752				

Reference Material

		Laboratory No.				Summary Statistics			
		101	102	106	111	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (Sec)	$\bar{X}$	47	43	27	52	42			
Std. Deviation	S	0	4	3	15		8	13	30
Variance	S^2	0	18	12	231				
Day 2									
Mean (Sec)	$\bar{X}$	47	55	27	47	44			
Std. Deviation	S	8	1	3	0		5	13	29
Variance	S^2	69	2	12	0				

Table 8. Phase II Results - Radiant Heat Ignition Test

Test Material 7 - Waste Oil/Sand Mixture

		Laboratory No.				Summary Statistics			
		101	102	106	111	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (Sec)	$\bar{X}$	211	122	82	191	151			
Std. Deviation	S	68	35	8	12		39	68	45
Variance	S^2	4622	1236	58	152				
Day 2									
Mean (Sec)	$\bar{X}$	210	57	130	113	127			
Std. Deviation	S	18	19	13	100		6	63	50
Variance	S^2	323	345	175	9852				

Reference Material

		Laboratory No.				Summary Statistics			
		101	102	106	111	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (Sec)	$\bar{X}$	43	38	25	45	38			
Std. Deviation	S	6	8	0	0		5	10	26
Variance	S^2	39	72	0	0				
Day 2									
Mean (Sec)	$\bar{X}$	46	41	27	54	42			
Std. Deviation	S	10	10	3	10		9	13	32
Variance	S^2	108	98	13	91				

Table 9. Phase II Results - Radiant Heat Ignition Test

Test Material No. 8 - Waste Solvent

		Laboratory No.					Summary Statistics			
		101	102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1										
Mean (Sec)	$\bar{X}$	31	54	65	72	84	61			
Std. Deviation	S	4	4	18	22	12		14	23	38
Variance	S^2	20	16	325	477	150				
Day 2										
Mean (Sec)	$\bar{X}$	38	49	52	56	ND	49			
Std. Deviation	S	3	7	10	2			6	9	19
Variance	S^2	9	50	108	3					

Reference Material

		Laboratory No.					Summary Statistics			
		101	102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1										
Mean (Sec)	$\bar{X}$	40	37	27	49	59	42			
Std. Deviation	S	2	10	3	5	8		6	13	31
Variance	S^2	4	98	13	28	69				
Day 2										
Mean (Sec)	$\bar{X}$	37	38	27	56		40			
Std. Deviation	S	2	6	3	12			7	13	33
Variance	S^2	4	32	13	153					

ND = No data reported

Table 10. Phase II Results - Radiant Heat Ignition Test

Test Material No. 9 - Sawdust/Kerosene

		Laboratory No.					Summary Statistics			
		101	102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1										
Mean (Sec)	$\bar{X}$	14	17	13	16	20	16			
Std. Deviation	S	2	11	6	2	7		6	6	35
Variance	S^2	3	124	33	5	46				
Day 2										
Mean (Sec)	$\bar{X}$	13	15	12	17	ND	14			
Std. Deviation	S	2	6	3	3			3	3	24
Variance	S^2	3	33	8	6					

Reference Material

		Laboratory No.					Summary Statistics			
		101	102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1										
Mean (Sec)	$\bar{X}$	43	33	23	49	71	44			
Std. Deviation	S	2	4	3	5	25		12	18	41
Variance	S^2	4	18	13	28	623				
Day 2										
Mean (Sec)	$\bar{X}$	46	44	30	41	ND	40			
Std. Deviation	S	15	3	0	2			7	9	23
Variance	S^2	212	8	0	3					

ND = No data reported

Table 11. Phase II Results - Flame Propagation Test

Test Material No. 3 - Cotton Fiber

		Laboratory No.			Summary Statistics			
		102	106	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1								
Mean (cm/Sec)	$\bar{X}$	3.7	2.6	6.5	4.3			
Std. Deviation	S	0.5	0.9	2.2		1.4	2.3	53.8
Variance	S^2	0.3	0.8	5.0				
Day 2								
Mean (cm/Sec)	$\bar{X}$	ND	2.65	ND	2.6			
Std. Deviation	S		0.92			*	*	*
Variance	S^2		0.84					

Reference Material

		Laboratory No.			Summary Statistics			
		102	106	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1								
Mean (cm/Sec)	$\bar{X}$	0.2	0.3	0.5	0.3			
Std. Deviation	S	0.01	0.02	0.08		0.04	0.16	52.1
Variance	S^2	-	-	0.006				
Day 2								
Mean (cm/Sec)	$\bar{X}$	0.2	0.3	ND	0.3			
Std. Deviation	S	0.1	0.08			0.1	0.1	36.1
Variance	S^2	0.01	-					

ND = No data reported
* = Value cannot be calculated from existing data

Table 12. Phase II Results - Flame Propagation Test

Test Material No. 4 - Polyurethane Foam

		Laboratory No.			Summary Statistics			
		106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1								
Mean (cm/Sec)	$\bar{X}$	0.3	0.3	0.4	0.33			
Std. Deviation	S	0.1	-	-		0.05	0.07	21.4
Variance	S^2	-	-	-				
Day 2								
Mean (cm/Sec)	$\bar{X}$	0.28	ND	ND	0.28			
Std. Deviation	S	0.01			-	*	*	*
Variance	S^2	-						

Reference Material

		Laboratory No.			Summary Statistics			
		106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1								
Mean (cm/Sec)	$\bar{X}$	0.4	0.2	0.5	0.4			
Std. Deviation	S	-	-	0.10		0.1	0.1	38.2
Variance	S^2	-	-	0.01				
Day 2								
Mean (cm/Sec)	$\bar{X}$	0.4	ND	ND	0.4			
Std. Deviation	S	-				*	*	*
Variance	S^2	-						

ND = No data reported
* = Value cannot be calculated from existing data

Table 13. Phase II Results - Flame Propagation Test

Test Material No.5 - Paint Waste

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	0.02	0.04	0.04	0.04	0.04			
Std. Deviation	S	0.01	0.004	0.008	0.005		0.01	0.01	28.8
Variance	S^2	-	-	-	-				
Day 2									
Mean (cm/Sec)	$\bar{X}$	0.03	0.03	ND	ND	0.03			
Std. Deviation	S	0.007	0.003				0.005	0.004	13.6
Variance	S^2	-	-						

Reference Material

		Laboratory No.				Summary Statistics			
		102	10[illegible]	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	0.2	0.3	0.4	0.5	0.4			
Std. Deviation	S	0.02	0	-	0.1		0.1	0.1	38.2
Variance	S^2	-	0	-	0.02				
Day 2									
Mean (cm/Sec)	$\bar{X}$	0.2	0.3	ND	ND	0.3			
Std. Deviation	S	0.04	0				0.02	0.07	24.2
Variance	S^2	-	0						

ND = No data reported

Table 14. Phase II Results - Flame Propagation Test

Test Material No. 8 - Waste Solvent

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	0.1	ND	0.2	0.1	0.1			
Std. Deviation	S	0.1		0.2	0.01		0.1	0.1	100.0
Variance	S^2	-		-	-				
Day 2									
Mean (cm/Sec)	$\bar{X}$	0.1	ND	ND	ND	0.1			
Std. Deviation	S	0.03					*	*	*
Variance	S^2	-							

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	0.4	ND	0.5	0.66	0.5			
Std. Deviation	S	0.01		-	-		0.01	0.13	26.3
Variance	S^2	-		-	-				
Day 2									
Mean (cm/Sec)	$\bar{X}$	0.4	ND	ND	ND	0.4			
Std. Deviation	S	0.1					*	*	*
Variance	S^2	-							

ND = No data reported
* = Value cannot be calculated from existing data

Table 15. Phase II Results - Flame Progation Test

Test Material No. 9 - Sawdust/Kerosene

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	0.1	0.2	0.1	0.04	0.11			
Std. Deviation	S	0.1	0.1	-	0.01		0.04	0.11	104.3
Variance	S^2	-	-	-	-				
Day 2									
Mean (cm/Sec)	$\bar{X}$	0.2	0.2	ND	ND	0.20			
Std. Deviation	S	0.04	0.02				0.03	0.02	12.3
Variance	S^2	-	-						

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/sec)	$\bar{X}$	0.4	0.4	0.4	0.4	0.4			
Std. Deviation	S	0.02	0.07	-	-		0.04	0.03	8.2
Variance	S^2	-	-	-	-				
Day 2									
Mean (cm/sec)	$\bar{X}$	0.4	0.5	ND	ND	0.4			
Std. Deviation	S	0.03	0.05				0.04	0.08	19.5
Variance	S^2	-	-						

ND = No data reported

Table 16. Phase II Results - Water Extinguishability Test

Test Material No. 3 - Cotton Fiber

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	3.4	7.6	1.9	4.8**	4.3			
Std. Deviation	S	0.4	0.6	0.5	4.0**		0.5	3.0	69.4
Variance	S^2	0.1	0.4	0.3	16.4**				
Day 2									
Mean (cm/Sec)	$\bar{X}$	2.9	2.5	1.9	ND	2.4			
Std. Deviation	S	0.4	2.6	0.4			1.5	1.3	55.3
Variance	S^2	0.2	6.8	0.2					

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	3.7	4.2	0.02	1.9	2.4			
Std. Deviation	S	0.4	-	-	0.8		0.5	1.9	81.0
Variance	S^2	0.2	-	-	0.7				
Day 2									
Mean (cm/Sec)	$\bar{X}$	2.9	2.8	0.02	ND	1.9			
Std. Deviation	S	0.2	0.3	-			0.2	1.9	100.0
Variance	S^2	0.05	0.07	-					

** = Data rejected by Cochran's test
ND = No data reported

Table 17. Phase II Results - Water Extinguishability Test

Test Material No. 4 - Polyurethane Foam

		Laboratory No.			Summary Statistics			
		106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1								
Mean (cm/Sec)	$\bar{X}$	2.2	2.4	5.3	3.3			
Std. Deviation	S	0.6	1.1	3.8		2.3	2.6	77.6
Variance	S^2	0.3	1.2	14.1				
Day 2								
Mean (cm/Sec)	$\bar{X}$	5.7	2.3	ND	4.0			
Std. Deviation	S	0.2	0.7			0.5	2.4	61.0
Variance	S^2	0.04	0.5					

Reference Material

		Laboratory No.			Summary Statistics			
		106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1								
Mean (cm/Sec)	$\bar{X}$	4.1	1.2	1.7	2.3			
Std. Deviation	S	0.8	0.2	0.7		0.6	1.6	70.7
Variance	S^2	0.6	0.05	0.5				
Day 2								
Mean (cm/Sec)	$\bar{X}$	5.0	0.9	ND	2.9			
Std. Deviation	S	2.9	0.05			2.1	3.4	116.2
Variance	S^2	8.6	-					

ND = No data reported

Table 18. Phase II Results - Water Extinguishability Test

Test Material No. 5 - Paint Waste

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	3.5	2.8	1.7	1.4	2.3			
Std. Deviation	S	0.6	1.2	0.1	0.1		0.7	1.1	49.2
Variance	S^2	0.4	1.5	0.01	-				
Day 2									
Mean (cm/Sec)	$\bar{X}$	3.4	3.5	1.6	ND	2.8			
Std. Deviation	S	0.5	1.2	0.2			0.8	1.3	44.8
Variance	S^2	0.3	1.4	0.02					

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	2.8	3.7	0.9	1.7	2.3			
Std. Deviation	S	0.2	0.7	0.1	0.7		0.5	1.3	56.3
Variance	S^2	0.05	0.4	0.01	0.4				
Day 2									
Mean (cm/Sec)	$\bar{X}$	2.7	3.9	0.9	ND	2.5			
Std. Deviation	S	0.2	1.1				0.5	1.6	62.6
Variance	S^2	0.05	1.3						

ND = No data reported

Table 19. Phase II Results - Water Extinguishability Test

Test Material No. 6 - Waste Oil

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{X}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	4.9	ND	ND	ND	4.9	*	*	*
Std. Deviation	S	0.8							
Variance	S^2	0.6							
Day 2									
Mean (cm/Sec)	$\bar{X}$	2.8	ND	ND	ND	2.8	*	*	*
Std. Deviation	S	0.7							
Variance	S^2	0.4							

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{X}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	4.2	ND	ND	ND	4.2	*	*	*
Std. Deviation	S	1.1							
Variance	S^2	1.1							
Day 2									
Mean (cm/Sec)	$\bar{X}$	2.4	ND	ND	ND	2.4	*	*	*
Std. Deviation	S	0.2							
Variance	S^2	0.03							

ND = No data reported
* = Value cannot be calculated from existing data

Table 20. Phase II Results - Water Extinguishability Test

Test Material No. 7 - Sand/Oil Mixture

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	2.5	ND	ND	ND	2.5	*	*	*
Std. Deviation	S	0.3							
Variance	S^2	0.1							
Day 2									
Mean (cm/Sec)	$\bar{X}$	2.9	ND	ND	ND	2.9	*	*	*
Std. Deviation	S	0.7							
Variance	S^2	0.5							

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	2.7	ND	ND	ND	2.7	*	*	*
Std. Deviation	S	0.9							
Variance	S^2	0.8							
Day 2									
Mean (cm/Sec)	$\bar{X}$	3.3	ND	ND	ND	3.3	*	*	*
Std. Deviation	S	0.3							
Variance	S^2	0.1							

ND = No data reported
* = Value cannot be calculated from existing data

Table 21. Phase II Results - Water Extinguishability Test

Test Material No. 8 - Waste Solvent

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	7.6	ND	3.9	3.1	4.9			
Std. Deviation	S	1.1		0.2	0.7		0.8	2.5	50.8
Variance	S^2	1.3		0.04	0.5				
Day 2									
Mean (cm/Sec)	$\bar{X}$	6.7	ND	3.7	ND	5.2			
Std. Deviation	S	0.9		0.2			0.6	2.2	41.9
Variance	S^2	0.8		0.03					

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	3.3	ND	1.0	2.1	2.1			
Std. Deviation	S	0.6		0.04	0.3		0.4	1.2	56.9
Variance	S^2	0.3		-	0.1				
Day 2									
Mean (cm/Sec)	$\bar{X}$	2.6	ND	0.9	ND	1.7			
Std. Deviation	S	1.1		0.01			0.7	1.3	78.3
Variance	S^2	1.1		-					

ND = No data reported

Table 22. Phase II Results - Water Extinguishability Test

Test Material No. 9 - Sawdust/Kerosene

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	3.6	2.6	3.3	1.2	2.7			
Std. Deviation	S	1.0	0.5	1.8	0.13		1.1	1.4	51.8
Variance	S^2	1.1	0.2	3.2	-				
Day 2									
Mean (cm/Sec)	$\bar{X}$	3.5	2.2	3.0	ND	2.9			
Std. Deviation	S	0.7	0.6	1.0			0.8	1.3	43.2
Variance	S^2	0.5	0.3	1.1					

Reference Material

		Laboratory No.				Summary Statistics			
		102	106	111	112	$\bar{\bar{X}}$	S_r	S	%RSD
Day 1									
Mean (cm/Sec)	$\bar{X}$	2.5	3.2	1.0	2.5	2.3			
Std. Deviation	S	0.2	0.6	0.05	0.2		0.3	1.0	41.7
Variance	S^2	0.03	0.3	-	0.05				
Day 2									
Mean (cm/Sec)	$\bar{X}$	3.1	3.2	0.9	ND	2.4			
Std. Deviation	S	0.3	1.0	0.05			0.6	1.4	57.9
Variance	S^2	0.1	1.0	-					

ND = No data reported